ANGCOR

An angular correlation program

M.N. Harakeh and L.W. Put

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I. Purpose

Excited states of nuclei can decay by γ-emission, or by particle emission if the decaying states lie in the continuum. If the m-state populations of these states are known then the angular distributions of the decay products could be calculated. In nuclear reactions one can usually calculate the m-state populations by assuming a certain reaction mechanism, e.g. in direct reactions (inelastic scattering, pick-up, stripping, charge exchange, etc.) the m-state population are calculated in DWBA. In this program ANGCOR the m-state populations obtained from DWUCK or CHUCK are used to calculate the angular correlation pattern of the decay products from the excited residual nucleus. It is obvious, however, that if the m-state populations are obtained by assuming other reaction mechanisms, the program could be easily modified to use these m-state population amplitudes to calculate angular correlation patterns.

II. Theoretical background

In this program, angular correlations are calculated for reactions of the type:

$$A(a,b)B^{*} \;\; \llcorner\!\!\rightarrow C + c$$

where c can be a γ-ray or a particle. Since the program treats the two cases differently, we will consider each case separately. But first, we discuss the general terms, the total transition amplitude and the transition amplitude for the reaction A(a,b)B.

In general, if only one intermediate state J_B is excited, the amplitude for the transition could be written [ref. 1]

$$\sum_{M_B} \langle J_C M_C | H | J_B M_B \rangle \langle \vec{K}_b, J_B M_B, s_b m_b | T | \vec{K}_a, J_A M_A, s_a m_a \rangle$$

where the transition amplitude for the reaction A(a,b)B is given by:

$$X_{m_a M_A ; m_b M_B}(\theta,\phi) = -\frac{(\mu_a \mu_b)^{1/2}}{2\pi\hbar^2}\left(k_b/k_a\right)^{1/2} \times \langle \vec{K}_b, J_B M_B, s_b m_b | T | \vec{K}_a, J_A M_A, s_a m_a \rangle$$

The cross section for exciting state B is then given by:

$$d\sigma/d\Omega_b = \left[(2J_A+1)(2s_a+1)\right]^{-1} \sum_{\substack{m_a m_b \\ M_A M_B}} \left| X_{m_a M_A, m_b M_B}(\theta,\phi)\right|^2$$

The transition amplitude for decay is:

$$\langle J_C M_C | H | J_B M_B \rangle$$

where H is the hamiltonian governing the decay, e.g. in case of γ-transitions, H will be the electromagnetic interaction.

The transition amplitude X could be rewritten in DWBA [ref. 2]

(1) $$X_{m_a M_A ; m_b M_B}(\theta,\phi) = -(\mu_a \mu_b)^{1/2}/(2\pi\hbar^2) \times (k_b/k_a)^{1/2} \times T_{DW}$$

$$T_{DW} = \langle \vec{K}_b, J_B M_B, s_b m_b | V | \vec{K}_a, J_A M_A, s_a m_a \rangle$$
$$= \sum_{\ell s j} \sqrt{2j+1}\; A_{\ell s j} \langle J_A j M_A, M_B - M_A | J_B M_B \rangle \; \beta_{\ell s j}^{m m_b m_a}(\vec{K}_b, \vec{K}_a$$

where $\vec{j} = \vec{J}_B - \vec{J}_A$ is the total angular momentum transfer

$\vec{s} = \vec{s}_a - \vec{s}_b$ is the spin transfer

$\vec{\ell} = \vec{j} - \vec{s}$ is the orbital angular momentum transfer

and $m = M_B' - M_A + m_b - m_a$

in zero range approximation [ref. 2]:

$$\beta_{\ell s j}^{m m_b m_a}(\theta) = (-)^{m+j+\ell+s_b-s_a} \; \beta_{\ell s j}^{-m,-m_b,-m_a}(\theta)$$

$$= \sum_{\substack{L_a L_b \\ J_a J_b}} i^{L_a - L_b - 1} \left[\frac{(L_b-m)!}{(L_b+m)!}\right]^{1/2} \begin{pmatrix} j & \ell & s \\ J_a & L_a & s_a \\ J_b & L_b & s_b \end{pmatrix}$$

$$\times P_{L_b}^{m}(\theta)\, f_{L_b J_b, L_a J_a}^{\ell s j} \sqrt{(2\ell+1)(2s+1)(2L_a+1)(2J_b+1)}$$

$$\times (2L_b+1) \langle J_b j\, m_b - m, m - m_b + m_a | J_a m_a \rangle$$

$$\times \langle L_a s_a 0\, m_a | J_a m_a \rangle \langle L_b s_b - m\, m_b | J_b m_b - m \rangle \langle L_b \ell 00 | L_a 0$$

The radial integrals :

$$f^{lsj}_{L_bJ_bL_aJ_a} = \frac{2\pi^{1/2}}{k_a k_b} \frac{B}{A} \int \chi^{(b)}_{L_bJ_b}\left(k_b, \frac{A}{B} r\right) F_{lsj}\ \chi^{(a)}_{L_aJ_a}(k_a, r)$$

See ref. 2 for more details on all terms and definitions.

DWUCK defines things slightly different, but the end result is the same [ref. 3] :

$$(2) \qquad T_{DWUCK} = \sqrt{\frac{4\pi}{k_a k_b}}\ \frac{C^2}{AB} \sum_{lsj} \sqrt{2l+1}\ B_{lsj} \langle J_A\, j\, M_A, M_B - M_A | J_B M_B \rangle S^{m m_a}_{lsj}$$

where $B_{lsj} = \sqrt{(2s+1)/(2s_a+1)}\ A_{lsj}$ and $m = M_B - M_A$

$$(3) \quad \text{and} \quad S^{m\, m_a\, m_b}_{lsj} = \sum_{L_b} \beta^{m\, m_a\, m_b}_{lsj\,;\,L_b}\ P^{m_a - m - m_b}_{L_b}(\theta)$$

where $\beta^{m\, m_a\, m_b}_{lsj\,;\,L_b}$ are the beta-functions (defined differently from Satchler, in fact $S_{\ell j}$ of DWUCK is proportional to $\beta_{\ell j}$ of Satchler) calculated by DWUCK in terms of channel (bB) angular momentum L_b, as well as projections of j, s_a and s_b. These beta-functions are read by program ANGCOR and used to calculate the amplitudes of the m-state populations.

[Note that in DWUCK $\sqrt{2l+1}\ \beta_{lsj}$ is printed in case of $\mu_a \neq \mu_b$ while only β_{lsj} is printed for $\mu_a = \mu_b$.]

In case more than one s or ℓ transfers contribute for the same j transfer to the excitation of a state then the amplitudes should be added coherently. Because of specific properties of the Clebsch-Gordon coefficient the summation over M_A and M_B makes different j-transfer amplitudes add incoherently [ref. 2].

In CHUCK the coupled differential equations are solved to obtain the final transition amplitude to the various coupled states. In this case CHUCK prints out the final transition amplitudes to channel c, $D^{l_c m_c}_{M_c\nu_c, M_{c_0}\nu_{c_0}}$, where now the cross section is:

$$d\sigma_c/d\Omega = 1/(2I_{c_0}+1)(2S_{c_0}+1) \sum_{M_c M_{c_0} \nu_c \nu_{c_0}}$$

$$\times \left| f_{coul}(\theta)\, \delta_{cc_0} \delta_{M_c M_{c_0}} \delta_{\nu_c \nu_{c_0}} + \sum_{l_c m_c} D^{l_c m_c}_{M_c \nu_c, M_{c_0}\nu_{c_0}} P^{m_c}_{l_c}(\theta) \right|^2$$

where c_0 stands for the elastic channel.

i Particle-particle correlation:

The angular correlation function is given by[5]:

$$W(\theta,\phi) = \sum_{i,f} \Big| \sum_n A_{i\to n} \; A_{n\to f} \Big|^2$$

where if more than one intermediate channel is excited, the amplitudes should be summed coherently over all intermediate states (labelled with n).

$$A_{i\to n} = X_{m_a M_A ; m_b M_B}(\theta,\phi)$$

$$\text{and } A_{n\to f} = \langle J_C M_C | H | J_B M_B \rangle$$

$$= \sum_j D_j^{n\to f} \langle \ell_j m_{\ell_j} s_c m_c | J_{p_j} m_{p_j} \rangle \langle J_{p_j} m_{p_j} J_C M_C | J_B M_B \rangle Y^{\ell_j}_{m_j}(\theta,\phi)$$

where D_j are complex numbers, which supposedly can be calculated if certain assumptions are made on H. Moreover,

$$\sum_f \sum_j \left[D_j^{n\to f}\right]^2 = 1, \text{ and } \quad m_{\ell_j} + m_c = m_{p_j}, \quad m_{p_j} + M_C = M_B .$$

In the program, one can vary the decay amplitudes D until a good fit for the angular correlation is obtained.

Then one can write:

$$(4) \qquad W(\theta,\phi) = \sum_{M_A m_a} \sum_{m_b} \sum_{M_C m_c} \Big| \sum_n \sum_{M_B^n = -J_B^n}^{J_B^n} A_{i\to n} \cdot A_{n\to f} \Big|^2$$

In this program up to two intermediate channels can be considered. This, of course, could be extended easily.

The normalization for the correlation function is: $\int W(\theta,\phi)\, d\Omega =$

ii Particle-gamma correlations

Here we follow the formulation of Rybicki et al. (1) who in turn follow the phase conventions of Rose and Brink (6). One can formulate things in terms of statistical tensors

$$\rho_{KQ}(J_B) = \sum_{M_B, M_B'} \rho_{M_B, M_B'} (-)^{J_B - M_B'} \langle J_B J_B M_B, -M_B' | K Q \rangle$$

where:

$$\rho_{M_B, M_B'} = \sum_{\substack{m_a m_b \\ M_A}} X_{m_a M_A, m_b M_B}(\theta,\phi) \; X^*_{m_a M_A, m_b M_B'}(\theta,\phi)$$

in this case :

$$\rho_{00}(J_B) = (2J_B+1)^{-1/2}\, tr\,\rho = \frac{(2J_A+1)(2s_a+1)}{\sqrt{2J_B+1}}\, d\sigma/d\Omega_b .$$

In the program the $\rho_{M_B,M_B'}$'s are calculated from DWUCK β's according to eqs. (1)-(3).

The double differential cross section:

(5) $$d^2\sigma/d\Omega_b d\Omega_\gamma = \frac{1}{4\pi}\left(\Gamma^B_{\gamma c}/\Gamma^B\right) W(\theta_\gamma,\phi_\gamma)\, d\sigma/d\Omega_b$$

where :

(6) $$W(\theta_\gamma,\phi_\gamma) = \sum_{KQ} f_K\, A_{KQ}(k_a,k_b)\, C_{KQ}(\theta_\gamma,\phi_\gamma)$$

f_K are geometrical attenuation factors and C_{KQ} is the renormalized spherical harmonic:

$$C_{KQ} = \left[4\pi/(2K+1)\right]^{1/2} Y_K^Q$$

A_{KQ} could be written in terms of the R_K functions of Rose and Brink[5]:

(7) $$A_{KQ}(k_a,k_b) = B_{KQ}(J_B)\, R_K(\gamma_{obs.})\, U_K(\gamma_{unobs.})$$

and

$$B_{KQ}(J_B) = \rho_{KQ}(J_B)/\rho_{00}(J_B)$$

$$R_K(\gamma) = \sum_{LL'} g_L\, g_{L'}\, R_K(LL'J_BJ_c)$$

$$g_L = \frac{\langle J_B \| T_L^{(\pi)} \| J_c\rangle/(2L+1)^{1/2}}{\left[\sum_{L'} |\langle J_B \| T_{L'}^{(\pi')} \| J_c\rangle|^2/(2L'+1)\right]^{1/2}}$$

normalized so that $R_0(\gamma) = 1$ and

$$\delta = g_{L+1}/g_L \qquad ; \qquad \sum_L g_L^2 = 1.$$

δ is real and phase conventions of Rose and Brink [ref. 6] are used.

Usually for γ-decay, only one or two multipolarities dominate (e.g. mixed M1/E2) in this case:

$$R_K(\gamma) = \left[R_K(LLJ_BJ_c) + 2\delta R_K(LL+1J_BJ_c) + \delta^2 R_K(L+1\,L+1\,J_BJ_c)\right]/(1+\delta^2)$$

R_K are functions defined by Rose and Brink[6]:

$$R_K^q(LL'J_1J_2) = (-)^{q+J_1-J_2+L'-L-K}\sqrt{(2J_1+1)(2L+1)(2L'+1)}$$

$$\times\langle LL'q\,-q|K0\rangle\, W(J_1J_1LL';KJ_2)$$

and
$$R_K(LL'J_1J_2) = R_K^{q=1}(LL'J_1J_2)$$

q is the γ-ray helicity (+1 or -1).

The above equation for the angular distribution is summed over q, hence assuming no polarization is observed.
The normalization of the correlation function is defined by:

$$\int W(\theta_\gamma, \phi_\gamma)\, d\omega_\gamma = 4\pi$$

For each unobserved γ-transition in the decay of the intermediate state preceding the observed transition a factor

$$U_K(\gamma_{unobs.}) = [U_K(LJ_1J_2) + \delta^2 U_K(L'J_1J_2)]/(1+\delta^2)$$

has to be introduced in eq. (7). These U_K's are ratios of Racah coefficients given by eq. (3.45) in ref. 6. The same U_K factor can be used in the case of unobserved particle decay of the intermediate state preceding the observed γ-transition (see e.g. ref. 7).

There are some selection rules that apply here:

$$0 \leq K \leq \mathrm{Min}\,(2L, 2J_B)$$

If only direction of γ-ray is observed, K = even.
symmetries: $\rho_{KQ}(J_B) = (-)^Q \rho_{K-Q}(J_B)^*$
Moreover, if the Z-axis is taken along $\vec{k}_a$ and the y-axis along $\vec{k}_a \times \vec{k}_b$, just like in DWUCK and CHUCK, then:

$$X_{-m_a-M_A,-m_b-M_B}(\theta_b,0) = 4\pi(-)^{J_A-J_B+s_a-s_b}(-)^{M_A-M_B+m_a-m_b}X_{m_aM_Am_bM_B}(\theta_b,$$

$\Delta\pi$ is parity change in the reaction.

This leads to:

$$\rho_{KQ}(J_B) = (-)^K \rho_{KQ}(J_B)^*$$

i.e. ρ_{KQ} is real/imaginary if K is even/odd.

Another way of getting ρ_{KQ} is outlined by Satchler (ref. 2). For historical reasons this option is still available in the program. Here ρ_{KQ} is defined:

$$\rho_{KQ} = (-)^Q \rho^*_{K-Q}(J_B) = (2J_B+1) \sum (-)^{J_B - J_A + j - K} \sqrt{(2j+1)(2j'+1)}$$
$$\times W(jj' J_B J_B ; K J_A)\, \tilde{\rho}_{KQ}(\ell s j, \ell' s' j')$$

where

$$\tilde{\rho}_{KQ}(\ell s j, \ell' s' j') = (-)^{j-j'-Q}\, \tilde{\rho}_{K-Q}(\ell' s' j', \ell s j)^*$$
$$= \sum_{\substack{m m_b \\ m_a}} (-)^{-j'-\mu+Q} B_{\ell s j}^{m m_b m_a} B_{\ell' s' j'}^{m-Q, m_b m_a *} \langle j j' \mu\, Q-\mu | K Q \rangle$$
$$\mu = m + m_a - m_b = M_B - M_A \quad ; \quad B_{\ell s j}^{m m_b m_a} = A_{\ell s j}\, \beta_{\ell s j}^{m m_b m_a}$$

$\beta_{\ell s j}^{m m_b m_a}$ are the functions as defined by Satchler (ref. 2).

In γ-decay only one intermediate channel can be considered. This is mainly because one is interested in studying γ-decay from bound states which are very narrow and don't overlap (i.e. no interference is present). If γ-decay from continuum states are to be considered, where more than one intermediate state could be excited at the same excitation energy, then the program has to be modified to take care of this.

iii) Particle fission correlations

Here one assumes that the fission fragments are emitted along the symmetry axis. If θ is the angle between the symmetry axis and the z-axis, then the angular correlation could be written[8,9] as follows:

$$W(\theta,\varphi) = \sum_{K_B} F(K_B) \sum_{\substack{m_a M_A \\ m_b J_B}} \left| \sum_{M_B} X^{J_B K_B}_{m_a M_A; m_b M_B} \; D^{J_B}_{M_B K_B}(\theta,\varphi,\psi) \right|^2$$

where K_B is the projection of J_B along the nuclear symmetry axis and various J_B's are assumed not to overlap in excitation energy (incoherent sum)

$$D^J_{MK}(\theta,\varphi,\psi) = (-)^{K-M} e^{-iM\varphi} e^{-iK\psi} d^J_{MK}(\theta)$$

for a state with definite $J_B K_B^{\pi}$, the angular correlation is given by

$$W^{J_B}_{K_B}(\theta,\varphi) \propto \sum_{\substack{m_a M_A \\ m_b}} \left| \sum_{M_B} X^{J_B K_B}_{m_a M_A; m_b M_B} (-)^{-M_B} e^{-iM_B\varphi} d^{J_B}_{M_B K_B}(\theta) \right|^2$$

where

$$d^J_{MK}(\theta) = \sum_S (-)^S \frac{\left[(J+M)!\,(J-M)!\,(J+K)!\,(J-K)!\right]^{1/2}}{(J-M-S)!\,(J+K-S)!\,S!\,(M-K+S)!} \times \left[\cos\theta/2\right]^{2J+K-M-2S} \left[\sin\theta/2\right]^{2S+M-K}$$

The normalization for the angular distribution is such that:

$$W^J_K(\theta) = \frac{2J+1}{2} \left| \sum_M a_M D^J_{MK}(\theta,0,0) \right|^2$$

$\therefore \int W^J_K(\theta)\, d\Omega = 2\pi$ or $\int W^J_K(\theta)\, d\cos\theta = 1$

Note: In DWUCK the beta-functions are multiplied by a phase $(-)^{ML}$ where $ML = M_A - M_B + m_a + m_b$ if ML is greater than zero. This is incorrect, it manifests itself by a reflection of the symmetry axis in the reaction plane. The correct treatment is to multiply the beta-functions by $(-)^{ML}$ only if ML is less than zero.

References

1) F. Rybicki et al., Nucl. Phys. A146 (1970) 659

2) G.R. Satchler, Nucl. Phys. 55 (1964) 1

3) DWUCK, preface and write up

4) CHUCK, preface and write up

5) G. Finkel et al., Phys. Rev. C19 (1979) 1782

6) H.J. Rose and D.M. Brink, Rev. of Mod. Physics 39 (1967) 306

7) S. Devons and L.J.B. Goldfarb, in "Handbuch der Physik", S. Flügge, Ed., (Springer Verlag, Berlin, 1957), vol. 42, p. 362
This reference includes detailed discussions on various cases of angular correlation studies.

8) J.J. Griffin, Phys. Rev. 116 (1959) 107

9) R. vandenBosch and J.R. Huizenga, Nuclear Fission, Academic Press New York (1973), p. 170

Description of input cards

The input and notation of this program has been made to conform with that of DWUCK and CHUCK where possible.

Card 0 — Title

Format: (20 A4)

Card 1 — Data: ICO(8), NC, M1

Format: (8I1, 12X, 5I2)

i (ICO)(i)

1 { 0 — Particle-Gamma angular correlation
1 — Particle-Particle angular correlation
2 — Particle-Particle-gamma angular correlations; the intermediate particle decay is unobserved
3 — Particle-fission fragment angular correlations

2 { 0 — $\mu_a = \mu_b$ in DWUCK (inelastic scattering)
1 — $\mu_a \neq \mu_b$ in DWUCK (transfer reactions)

3 { 0 — Calculate ρ_{KQ} from $\rho_{MM'}$
1 — Calculate ρ_{KQ} from $\tilde{\rho}_{KQ}$ $(\ell sj, \ell' s' j')$

4 { 0 — Only one intermediate state $\Psi(J_B)$ is excited.
1 — Two intermediate states $\Psi(J_B)$ and $\Psi(J_B')$ are excited. This option is available only for particle decay. In this case only one J-transfer and one J-decay is allowed per intermediate state.

5 { 0 — Beta functions (β) are read from DWUCK file.
1 — Transition amplitudes (D) are read from CHUCK file.

6 { 0 — New DWUCK/CHUCK information
1 — Same DWUCK/CHUCK information as previous case.

7 { 0 — Print DWUCK β's/CHUCK D's.
1 — Suppress printing DWUCK β's/CHUCK D's.

8 { 0 — Print angular correlation output.
1 — Suppress printing angular correlation output. (Only χ^2 will be printed)

9 { 0 — Beam axis is z-axis

NC	(≤3) number of cascades in case of gamma-decay. If ICO(1).EQ.2, NC is also the number of γ-cascades and is restricted to ≤ 2
MI	.GE.0 number of experimental data (MI ≤ 10)
	.LT.0 same experimental data as in previous case.

<u>Card 2</u> Reaction spins definition card (should be deleted if ICO(6) = 1)

Data: LP, JA, ISA, JB(1), JB(2), ISB, ISTR, RSCALE

Format: (7I3, 9X, F10.5)

LP	Number of partial waves used in computation; must be equal to value used in DWUCK or CHUCK (≤150)
JA	Twice angular momentum of target nucleus.
ISA	Twice spin of projectile
JB(1)	Twice angular momentum of 1st intermediate state.
JB(2)	Twice angular momentum of 2nd intermediate state
ISB	Twice spin of ejectile
ISTR	Twice spin transfer in the reaction
RSCALE	A scaling factor of 2nd intermediate state cross section; to allow various ratios of excitations of both states in DWUCK. Note if CHUCK is used this is not necessary.

N.B. In case of γ-ray or fission only one intermediate state is allowed; leave JB(2) blank.

<u>Card 3</u> Transfer angular momentum card (delete if ICO(6) = 1)

Data: NLTR, LTR(1),..., LTR(NLTR), JTR(1),...,JTR(NLTR)

Format: (18I3)

NLTR	Number of separate angular momentum transfers (≤8)
LTR(i)	The value of the ith orbital angular momentum transfer
JTR(i)	Twice the value of the ith angular momentum transfer.

N.B. If ICO(4) = 1, NLTR should be 2 and there should be one value of LTR and of JTR for each of the two intermediate states considered.

If ICO(1) = 1 or 2

Card 4A — Particle decay parameters

1) first card of this set

Data: JC, ISC, NLDEC

Format: (18I3)

JC — Twice angular momentum of residual nucleus.

ISC — Twice spin of decay particle.

NLDEC — Number of separate angular momentum decays (NLDEC=2 if ICO(4)=1 in other cases NLDEC $\leq$ 3

2) NLDEC cards with:

Data: LDEC(i), JDEC(i), DELTA(i), DMAX(i), INCR(i)

Format: (2I3, 4X, 3F10.5)

LDEC(i) — Value of ith orbital angular momentum decay

JDEC (i) — Twice the value of the ith total angular momentum decay; for ICO(4) = 1, LDEC(i) and JDEC(i) correspond with JB(i) [card 2]; DELTA has no meaning in this case.

DELTA(i) — Mixing ratio for the ith decay amplitude; in this version only real DELTA values are allowed. If only one L-decay amplitude is used, the program will assume DELTA(i) = 1.

DMAX(i) — Maximum value of DELTA(i) for which angular correlation should be calculated.

INCR(i) — Step size to increase DELTA(i) value. (Up to DMAX(i)).

If ICO(1) = 0 or 2

Card 4B — Gamma-ray decay parameters

NC cards with information about the NC transitions in the γ-ray cascade.

Data: L (i), J2(i), AMIN(i), AMAX(i), STEP(i)

Format: (2I3, 4X, 3F10.5)

L (i) — Lowest multipolarity in transition; mixing with multipolarity L + 1 is assumed.

J2 (i) — Twice the spin-value of state to which the particular transition leads.

AMIN(i) Minimum value of arctan(δ), with δ being the mixing ratio between L + 1 and L transitions ($\delta = g_{L+1}/g_L$)

AMAX(i) Maximum value of arctan (δ)

STEP(i) Step size in arctan (δ)

If ICO(1) = 3

<u>Card 4C</u> Projection of the total angular momenta on the nuclear symmetry axis.

Data: K_A, K_B

Format: (18I3)

K_A Twice the projection of J_A on the nuclear symmetry axis

K_B Twice the projection of J_B on the nuclear symmetry axis

<u>Card 5</u> Geometrical attenuation coefficients [illegible] ISET(i) [illegible] this card is skipped!

Data: ZW(i), i = 1,3

Format:(3F10.5)

ZW(i) Attenuation coefficients with which the C_2^Q (cos θ), C_4^Q(cos θ) and C_6^Q(cos θ) terms in the angular correlation should be multiplied(see eq. (6)).

N.B. This option is available only for γ-decay.

<u>Card 6</u> Ejectile polar angle and decay (particle/gamma ray) azimuthal angle.

Data: ANG, PHID, RECANG, RECPHI, RECPSI

Format: (8F10.5)

ANG The polar angle of the scattered particle (ejectile)

PHID Azimuthal angle of the decay particle/gamma-ray. PHID = $0^\circ/180^\circ$ represents decay in the reaction plane on the same/opposite side as the ejectile if compared to the beam axis. PHID can take all values between 0° and 180°.

RECANG is the recoil angle (positive).

If ANG is as the previous case, the calculation of the m-state population amplitudes is skipped.

Card 7 M1 cards with experimental data (only if $M1 > 0$, see card 1)

Data: AN1(i), PH1(i), C1(i), EC1(i)

Format: (4F10.5)

AN1(i) ith polar angle for which angular correlation has been measured.

PH1(i) ith azimuthal angle

C(i) ith value of angular correlation (arbitrary units)

EC(i) Absolute error in C(i) (same units as C(i))

N.B. $|M1| \leq 10$

Card 8 Vertical and horizontal scales for decay angular correlation. If ANG is the same as the previous case, this card is ~~not~~ necessary..

Data: NPLOT, NANGP

Format: (18I3)

NPLOT Vertical scale of the angular correlation plot. Full scale corresponds to NPLOT times regular scale of angular correlations.

NANGP Number of intervals into which 180° of the polar angular correlation plot/print is subdivided so e.g. NANGP = 31 gives $\Delta\Theta = 180/(31-1) = 6^{\circ}$.

Here the program goes back and starts reading card 0. Program stops if it finds an EOF card at this position.